Long-term follow up after endodontic microsurgery

: The changing patterns between one year and over four years' follow up

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A Masters Thesis
Submitted to the Department of Dentistry
and the Graduate School of Yonsei University
in partial fulfillment of the
requirements for the degree of
Master of Dental Science

Taekjin Nam

June 2012

This certifies that the masters thesis
of Taekjin Nam is approved.

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The Graduate School
Yonsei University
June 2012

감사의 글

높은 뜻을 품고 신촌 땅에 들어선지도 10 년에 접어 들었습니다. 낯선 교정과 환경들이 이제는 너무나도 익숙해졌고, 신촌 세브란스 치과대학 병원은 집과 같은 마음의 평안함을 허락합니다. 어느 곳에 가서 무엇을 하든지 마음의 고향으로 영원히 남아 있을 것입니다. 부족한 제가 이 결실을 맺기까지 관심 가져 주시고 기도해 주신 모든 분들께 일일이 찾아 뵙고 인사 드리는 것이 도리이나 우선 이 지면을 빌어 감사의 인사를 드리고자 합니다.

먼저, 지금의 제가 있기까지 이끌어주셨고, 현재에도 미래에도 역사하실 하나님께 영광을 돌립니다.

연구와 강의로 바쁘신 가운데도 3 년간의 보존과 수련기간 내내 지도와 조언을 아끼지 않으시고, 세상을 향한 넓은 안목을 가질 수 있게 많은 가르침을 주신 김의성 교수님께 감사를 드립니다. 그리고 항상 새로운 지식과 세상을 업데이트 해주시고 비전을 제시해 주신 정일영교수님과 세세한 첨삭과 따듯한 배려를 통하여 항상 해낼 수 있다는 용기와 자신감을 부여해주시고 편안한 마음을 가질 수 있게 해주신 신수정 교수님께 감사를 드립니다.

10 년 전 치과대학에 입학했을 때부터 현재까지 지켜봐 주시고 가르침을 베풀어 주신 노병덕 교수님께 감사를 드립니다. 진료실 안에서는 치과의사로서의 본을 보여 주시고 진료실 밖에서는 세상을 살아가는 방법을 전수해 주신 이찬영 교수님, 이승종 교수님, 박성호 교수님, 박정원 교수님, 신유석 교수님, 송민주 교수님께도 이 지면을 빌어 감사의 말씀을 드립니다.

동고동락한 사랑하는 동기 김유경, 김현주, 정재훈, 조신연, 김보나, 원유경에게 함께 있어줘서 고맙다는 말을 전하고 싶습니다. 그리고 함께 했던 의국 선·후배님들과 많은 추억들 잊지 못할 것이고, 소중한 만남에 감사를 드립니다.

본과 시절부터 늘 저의 곁을 지켜준 지금은 영원한 짝꿍이 된 사랑하는 아내에게 그동안 표현하지 못한 저의 마음을 전하고 싶습니다. 저를 낳아주시고 길러주시고 항상 기도로 중보해주시는 아버지, 어머니 그리고 택언, 택함, 택희와, 부족한 저에게 사랑스러운 딸을 허락해주신 장인어른, 장모님, 나라형님에게 고맙고 사랑한다는 말을 전하고 싶습니다.

뒤돌아 볼 때 더 열심히 임하지 못했던 순간들이 아쉽지만, 최선을 다한 지난 시간들이었기에 후회는 없습니다. 이제 또 다른 새로운 발걸음을 내디디려고 합니다. 새로운 것을 배우고 익히는 것을 게을리 하지 않을 것입니다. 하나님께서 주신 높은 뜻을 품고 세상과 사람을 사랑하는 이가 되겠습니다. 감사합니다.

2012 년 여름 연세대학교치과대학병원 4 층 보존과에서

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Many outcome studies for endodontic microsurgery were done in a period of approximately one-year. Controversy exists on whether the postoperative one-year observation results are maintained over longer follow up. The aim of this study is to examine and compare the post-surgical results of the endodontic microsurgery under two time frames, one-year follow up, and over four years after the surgery. We analyzed patterns of stability, healing, deterioration, and the causes of failure of microendodontic surgery.

The clinical database of the Department of Conservative Dentistry at the College of Dentistry, Yonsei University in Seoul, Korea, was searched for patients with a history of endodontic microsurgery performed from 2004 to 2007 and evaluated clinically and radiographically at the point of one-year and over four years after endodontic microsurgery. All evaluations were performed using the Molven criteria and PAI scoring system.

Among the 550 cases with endodontic microsurgery, 103 cases were included in this study. In Molven criteria, of 92 cases classified as success at one-year, 89 cases (96.7%) remained so, whereas 3 cases (3.3%) regressed to failure at long-term follow up. Conversely, of 11 cases regarded as failure at one-year,

3 cases (27.3%) progressed to success group. After long-term follow up, the failure group after one-year follow up did not become more healed or deteriorative than the success group.

In PAI scoring system, of 94 cases classified as successful results (score 1-3) at one-year, 90 cases (95.7%) remained so at long-term follow up, whereas 4 cases (4.3%) regressed to failure results (score 4-5). Conversely, of 9 cases classified as failure results at one-year, 2 cases (22.2%) progressed to successful results. After long-term follow up, the failure group after one-year follow up did not become more healed than in the success group. On the other hand, the failure group after one-year follow up became more deteriorative than in the success group.

In spite of limitations, through this study, we were able to conclude that long-term outcomes of endodontic microsurgery can be predicted by one-year outcomes. During the long-term period, PAI scoring system was more sensitive than Molven criteria in observation of healing pattern changes. However, clinically, the PAI scoring system and the Molven criteria did not show significant differences in assessing the success and failure of the endodontic microsurgery.

Keywords: Apical surgery; Endodontic microsurgery; Molven criteria; PAI scoring system; Long-term study; Change pattern; Outcome

Long-term follow up after endodontic microsurgery

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I. Introduction

Despite the fact that nonsurgical endodontic therapy is a treatment with a high success rate ranging of 86 – 98% (Friedman et al., 2003; Setzer et al., 2011), failures still occur. Therefore, further surgical or nonsurgical retreatment is necessary at times (Ng et al., 2007; Torabinejad et al., 2007). Nonsurgical retreatment is the first option for treating persistent apical periodontitis (Siqueira, 2001). However, when nonsurgical retreatment is thought to be

impractical or ineffective, endodontic surgery becomes necessary (Gutmann and Harrison, 1985). In particular, when a persistent lesion is associated with a periapical cyst or the canal anatomy is complex, surgical retreatment is the first choice (Barone et al., 2010; S. Kim and Kratchman, 2006).

During the previous decades, numerous surgical instruments and materials, including microscope, root-end filling materials and ultrasonic tips were introduced. Such technologies were on the leading edge of technology of endodontic microsurgery in the 1990s (S. Kim and Kratchman, 2006). This improved understanding of the apical anatomy, and increased the success rate of treatments by allowing easier identification of shallower resection angles that conserve cortical bone and root length (S. Kim and Kratchman, 2006).

Compared to the conventional root-end surgery's variable success rate of 37- 91% (Friedman, 2005), the implementation of microsurgical principles can improve endodontic surgery's success rate to 90% (E. Kim et al., 2008; Tsesis et al., 2009). According to Setzer et al. (Setzer et al., 2010) the surgical techniques have improved compared to conventional endodontic surgery, and this naturally led to the increase of the success rate for endodontic microsurgery.

In performing outcome studies in endodontic field, radiological evaluations as well as clinical evaluations have been performed, and selecting the radiological evaluation protocol is a critical factor which can change the results. There are two major evaluation systems for the healing process of post endodontic surgery. One is Andreasen and Rud (Andreasen and Rud, 1972; Rud et al.,

1972a, 1972b) and Molven et al. (Molven et al., 1987) 's process, analyzing the correlation between histology and radiography. This evaluation system has four different groups for the classification of healing: complete healing, incomplete healing, uncertain healing, and unsatisfactory healing (Rud et al., 1972b). The other scoring system is the periapical index (PAI) for evaluating apical periodontitis. This has an ordinal scale ranging from 1 (healthy) to 5 (severe periodontitis) (Orstavik et al., 1986).

Furthermore, the evaluating point after surgery can act as another important factor. Most research on success of endodontic surgery have performed the evaluations one-year after the surgery (Chong et al., 2003; Christiansen et al., 2009; Filippi et al., 2006; E. Kim et al., 2008; Richard et al., 1999; Taschieri et al., 2006; Taschieri et al., 2008; von Arx et al., 2003). For most cases, one-year follow up allows for a clear evaluation of the surgery. However, there are cases with partially healed or uncertain radiographic features after one-year (Halse et al., 1991). The longer the examination period, the more clearly success can be distinguished. According to Rud et al. (Rud et al., 1972a), a four-year observation period is recommended for the final follow up in endodontic surgery. Yet, there are other authors who report that cases which were considered to be healed within one-year stay healed after long term follow up (Rubinstein and Kim, 2002; Zuolo et al., 2000). Likewise, controversy exists on whether the postoperative one-year observation results are maintained over longer follow up (Friedman, 2011; Setzer, 2011).

With this background, the aim of this study is to examine and compare the

post-surgical results of the endodontic microsurgery under two time frames, one-year follow up, and over four years (up to eight years) after the surgery. All evaluations were performed using the Molven criteria (Molven et al., 1987) and PAI scoring system (Orstavik et al., 1986). We analyzed patterns of stability, healing, deterioration, and the causes of failure of microendodontic surgery.

II. Materials and Methods

1. Case selection

The clinical database of the Department of Conservative Dentistry at the College of Dentistry, Yonsei University in Seoul, Korea, was searched for patients with a history of endodontic microsurgery performed from February 2004 to December 2007 and evaluated clinically and radiographically at the point of one-year and over four years after endodontic microsurgery.

2. Surgical procedures

All surgical procedures with the exception of the incisions, flap elevation, and suturing were performed using an operating microscope (OPMI PICO; Carl Zeiss, Göttingen, Germany). All clinical procedures follow those reported in previous studies (E. Kim et al., 2008; Song et al., 2011) and were performed by the endodontic faculties and residents. The flap was reflected after nerve (regional) block and infiltration anesthesia, and osteotomy was performed. After removing the soft-tissue debris, 2 to 3 mm of root tip with a 0 to 10 bevel angle was sectioned with a fissure bur under copious water irrigation. The resected root surfaces were stained with methylene blue and inspected with micromirrors (ObturaSpartan, Fenton, MO, USA) under 20 X to 26 X magnification to examine the cleanness of the root-end preparation and to search for other anatomic details. The root-end preparation extending to 3 mm

into the canal space along the long axis of the root was made using KiS ultrasonic tips (ObturaSpartan) driven by a Piezoelectric ultrasonic unit (Spartan MTS, ObturaSpartan). The root-end filling material used was an Intermediate Restorative Material (Caulk Dentsply, Milford, DE), Super EBA (Harry J. Bosworth, Skokie, IL), or ProRoot MTA (Dentsply, Tulsa, OK), which was selected according to operators' preference. The wound site was closed and sutured with 5-0 monofilament sutures, and a postoperative radiograph was taken to check for correct placement and an absence of excess material in the surgical site. A postoperative mouthwash (0.2% chlorhexidine gluconate, Hexamedin; Bukwang Phar Co, Ansan, Korea) was routinely prescribed, and the sutures were removed 4 to 7 days later.

3. Records review and Radiographic Evaluation

The clinical data including the signs and/or symptoms or loss of function, tenderness to percussion or palpation, subjective discomfort, mobility, sinus tract formation or periodontal pocket formation, postoperative complications, and presence or absence of a restoration were included in the operation record form. This operation record form was reviewed, and clinical data was collected.

The postoperative radiographs taken at one-year and over four years were evaluated independently by two examiners using the same criteria used by Molven et al. (Molven et al., 1987, 1996) and PAI scoring system used by Orstavik et al. (Orstavik et al., 1986). The two examiners standardized the evaluation criteria before case analyses. Any disagreement regarding the clinical

outcome was resolved by discussion until agreement between the two examiners was reached.

Healing classification by Molven criteria (Molven et al., 1987) was as follows: (1) complete healing, (2) incomplete healing, (3) uncertain healing, and (4) unsatisfactory healing.

The periapical index (PAI) system provides an ordinal scale of 5 scores ranging from 1 (healthy) to 5 (severe periodontitis with exacerbating features). PAI scoring system healing classification is presented in Table 1 (Huumonen et al., 2003; Orstavik et al., 1986; Orstavik et al., 2004; Penesis et al., 2008). Instructions for scoring using the PAI were defined as follows: 1) Find the reference radiograph where the periapical area most closely resembles the periapical area you are studying. Assign the corresponding score to the observed root. 2) When in doubt, assign higher score. 3) For multirooted teeth, use the highest of the scores given to the individual roots. 4) All teeth must be given a score.

Table 1. The periapical index (PAI)

PAI Score	Description of radiographic findings
1	Normal periapical structures
2	Small changes in bone structure
3	Change in bone structure with some mineral loss
4	Periodontitis with well-defined radiolucent area
5	Severe periodontitis with exacerbating features

4. Assessment of outcome

Success and failure were judged clinically and radiographically. Cases with the same results between one-year and long-term follow ups were categorized as 'Stable case'. 'Healing case' was defined as cases that changed to better categories, and on the contrary, cases that changed to worse categories were defined to 'Deteriorative case'. Cases that were extracted or that had undergone re-surgery were regarded as the worst group.

1) Molven criteria

The criteria for a successful outcome included the absence of clinical signs and symptoms and radiographic evidence of complete or incomplete healing. The criteria for failure included any clinical signs and/or symptoms or radiographic evidence of uncertain or unsatisfactory healing.

2) PAI scoring system

The criteria for a successful outcome included the absence of clinical signs and symptoms and radiographic evidence of score 1 – 3. The criteria for failure included any clinical signs and/or symptoms or radiographic evidence of score 4 or 5.

5. Evaluation of cause of failure in previous microsurgery

Cases with a one-year follow up result who had undergone endodontic micro-resurgery or root resection or extraction after the long term follow up were analyzed retrospectively to attempt to find the causes of failure from the records.

6. Statistical analysis

Interexaminer agreement was assessed with the Cohen weighted kappa statistics. Cases were divided into success and failure group and Cohen kappa statistical analysis was performed to compare the results between one-year and at least four-year follow up. The changing pattern between one-year and long term follow ups was divided into stable case, healing case or deteriorative case and compared by using logistic regression. All statistical analysis was two-tailed, and was performed with SPSS v18.0 software (IBM Corp, Somers, NY, USA), and interpreted at the 5% level.

III. Results

Of 550 cases with a history of endodontic microsurgery performed between February 2004 and December 2007, 283 cases were available for follow up. Among them, the excluded cases were as follows: 13 cases had undergone endodontic micro-resurgery or root resection within one-year, 17 cases were not evaluated at the point of one-year follow up, 150 cases were not evaluated at the point of four or more years. Finally 92 cases with both one-year and long-term follow up results, and 11 cases with one-year follow up and treatment failure after long-term follow up, were included in this study. Table 2 lists the distribution of cases categorized by variables of interest. Distribution of the cases in relation to the maximum follow up period is shown in Table 3.

Table 2. Case Distribution

Variables		No. of teeth
Sex	Male	43
	Female	60
Age	21-30	10
	31-40	27
	41-50	17
	51-60	21
	61-70	18
	71-80	10
Tooth type		
Anterior	Mx	42
	Mn	16
Premolar	Mx	18
	Mn	5
Molar	Mx	11
	Mn	11

Mx=maxillary, Mn=mandible

Table 3. Distribution of cases related to maximum follow up period

Follow up period	No. of teeth
4y	47
5y	17
6y	12
7y	15
8y	1

y=year

1. Molven criteria

Change in outcomes (by Molven criteria) between the one-year and long-term (four or more year) follow up is shown in Table 4. The kappa value of 0.69 shows good agreement between the one-year and the long-term follow up ($p<.0001$).

Table 4. Changing in outcome at one-year and the long-term follow up after endodontic microsurgery with Molven criteria

Healing classification					Changing pattern		
One-year follow up		Long-term follow up					
Category	n	Category	n	%S	Category	n	%S
Complete	73	Complete	69	94.5	Stable	69	94.5
		Incomplete	1	1.4	Deteriorative	1	1.4
		Uncertain	0	-	Deteriorative	0	-
		Unsatisfactory	3	4.1	Deteriorative	3	4.1
		Subtotal	73		Subtotal	73	
Incomplete	19	Complete	13	68.4	Healing	13	68.4
		Incomplete	6	31.6	Stable	6	31.6
		Uncertain	0	-	Deteriorative	0	-
		Unsatisfactory	0	-	Deteriorative	0	-
		Subtotal	19		Subtotal	19	

Uncertain	4	Complete	0	–	Healing	0	–
		Incomplete	3	75.0	Healing	3	75.0
		Uncertain	0	–	Stable	0	–
		Unsatisfactory	1	25.0	Deteriorative	1	25.0
		Subtotal	4		Subtotal	4	
Unsatisfactory	7	Complete	0	–	Healing	0	–
		Incomplete	0	–	Healing	0	–
		Uncertain	0	–	Healing	0	–
		Unsatisfactory	7	100	Stable	7	100
		Subtotal	7		Subtotal	7	
Total(n)	103	Complete	82	79.6	Stable	82	79.6
		Incomplete	10	9.7	Healing	16	15.5
		Uncertain	0	–	Deteriorative	5	4.9
		Unsatisfactory	11	10.7			

%S, proportion of subtotal

The healing categories at one-year after endodontic microsurgery were distributed as follows. Of 103 cases, 92 cases (89.3%) were included in the success category, 73 cases with complete healing and 19 cases with complete healing. Eleven cases (10.7%) were included in the failure category, 4 cases with uncertain healing and 7 cases with unsatisfactory healing. The weighted kappa value was 0.78, which shows the agreement between the examiners was highly consistent ($p<.0001$).

At long-term follow up, the healing categories were distributed as follows. Of 103 cases, 92 cases (89.3%) were included in the success categories, 82 cases with complete healing and 10 cases with incomplete healing. Eleven cases (10.7%) failed, so extraction or re-surgery was performed. The weighted kappa value was 0.84, which shows the agreement between the examiners was highly consistent ($p<.0001$).

Of 92 cases classified as complete/incomplete healing at one-year, 89 cases (96.7%) remained so at long-term follow up, whereas 3 cases (3.3%) regressed to uncertain/unsatisfactory healing at long-term follow up. Conversely, of 11 cases classified as uncertain/unsatisfactory healing at one-year, 3 cases (27.3%) progressed to complete/incomplete healing. Therefore the numbers of teeth classified as complete/incomplete healing were the same at one-year and after long-term follow up, counting 92 cases.

Healing groups were divided up to success group (complete, incomplete) and failure group (uncertain, unsatisfactory), and the distribution of stable/healing/deteriorative cases were analyzed individually. Of 103 cases, 82 cases were stable cases and 16 cases were healing cases and 5 cases were deteriorative cases. Logistic regression was performed to determine the probability of change into deteriorative or healing categories rather than remaining stable, comparing the success group and failure group. Cases that were extracted or that had undergone re-surgery were regarded as the worst group (unsatisfactory healing group). The results are described in Table 5. After long-term follow up, the failure group after one-year follow up did not become more healed than the success group ($p=0.2291$, odds ratio=2.473). Also after long-term follow up, the failure group after one-year follow up did not become more deteriorative than the success group ($p=0.4060$, odds ratio=2.679). In other words, both success group and failure group remained stable after long-term follow up.

Table 5. Status change on follow up comparing success group and failure group by logistic regression with Molven criteria

	Odds ratio	95% CI		P-value
Healing=1/ Stable=0	2.473	0.566	10.809	0.2291
Deterioration=1/ Stable=0	2.679	0.262	27.371	0.4060

CI = confidence interval

2. PAI scoring system

Outcome change (by PAI scoring system) between the one-year and long-term (over four year) follow up is shown in Table 6. The kappa value was 0.67, good agreement between one-year and long-term (over four year) follow up ($p<.0001$).

Table 6. Changing in outcome at one-year and the long-term follow up after endodontic microsurgery with PAI scoring system

Healing classification					Changing pattern		
One year follow up		Long-term follow up					
Category	n	Category	n	%S	Category	n	%S
Score 1	54	Score 1	50	92.6	Stable	50	92.6
		Score 2	2	3.7	Deteriorative	2	3.7
		Score 3	0	-	Deteriorative	0	-
		Score 4	0	-	Deteriorative	0	-
		Score 5	2	3.7	Deteriorative	2	3.7
		Subtotal	54		Subtotal	54	
Score 2	27	Score 1	16	59.3	Healing	16	59.3
		Score 2	10	37.0	Stable	10	37.0
		Score 3	0	-	Deteriorative	0	-
		Score 4	0	-	Deteriorative	0	-
		Score 5	1	3.7	Deteriorative	1	3.7
		Subtotal	27		Subtotal	27	

Score 3	13	Score 1	4	30.8	Healing	4	30.8
		Score 2	5	38.5	Healing	5	38.5
		Score 3	3	23.1	Stable	3	23.1
		Score 4	0	–	Deteriorative	0	–
		Score 5	1	7.7	Deteriorative	1	7.7
		Subtotal	13		Subtotal	13	
Score 4	7	Score 1	1	14.3	Healing	1	14.3
		Score 2	0	–	Healing	0	–
		Score 3	1	14.3	Healing	1	14.3
		Score 4	0	–	Stable	0	–
		Score 5	5	71.4	Deteriorative	5	71.4
		Subtotal	7		Subtotal	7	
Score 5	2	Score 1	0	–	Healing	0	–
		Score 2	0	–	Healing	0	–
		Score 3	0	–	Healing	0	–
		Score 4	0	–	Healing	0	–
		Score 5	2	100	Stable	2	100
		Subtotal	2		Subtotal	2	
Total(n)	103	Score 1	71	68.9	Stable	65	63.1
		Score 2	17	16.5	Healing	27	26.2
		Score 3	4	3.9	Deteriorative	11	10.7
		Score 4	0	–			
		Score 5	11	10.7			

%S, proportion of subtotal

The PAI scores at one-year after endodontic microsurgery follow. Of 103 cases, 94 cases (91.3%) were included in successful results (score 1-3), 54 cases were score 1, 27 cases were score 2 and 13 cases were score 3. Nine cases (8.7%) (7 cases with score 4 and 2 cases with score 5) were regarded as failure results (score 4-5). The weighted kappa value was 0.49, which shows the agreement between the examiners was moderately consistent ($p<.0001$).

The PAI scores at long-term follow up after endodontic microsurgery are listed below. Of 103 cases, 92 cases (89.3%) were included in successful results, 71 cases with score 1, 17 cases with score 2, and 4 cases with score 3. Eleven cases (10.7%) failed, so extraction or re-surgery was performed. The

weighted kappa value was 0.43, which shows the agreement between examiners was moderately consistent (p<.0001).

Of 94 cases classified as successful results (score 1-3) at one-year, 90 cases (95.7%) remained so at long-term follow up, whereas 4 cases (4.3%) regressed to failure results (score 4-5). Conversely, of 9 cases classified as failure results (score 4-5) at one-year, 2 cases (22.2%) progressed to successful results (score 1-3). On balance, the number of teeth classified as successful (score 1-3) decreased from 94 cases at one-year to 92 cases at long-term follow up after treatment, a reduction of 2%.

In PAI scoring system, healing groups were divided into success group (score1-3) and failure group (score 4-5), and the distribution of stable/healing/deteriorative cases were analyzed individually. Of 103 cases, 65 cases were stable, 27 cases were healing and 11 cases were deteriorative. Logistic regression was performed to determine the probability of change into deteriorative or healing categories, comparing the success group and failure group. Cases that were extracted or that had undergone re-surgery were regarded as the worst group (score 5). The results are described in Table 7. After long-term follow up, the failure group after one-year follow up did not become more healed than in the success group (p=0.3686, odds ratio=2.519). On the other hand, after long-term follow up, the failure group after one-year follow up became more deteriorative than in the success group (p=0.0005, odds ratio=26.240).

Table 7. Status change on follow up comparing success group and failure group by logistic regression with PAI scoring system

	Odds ratio	95% CI		P-value
Healing=1/Stable=0	2.519	0.336	18.873	0.3686
Deterioration=1/ Stable=0	26.240	4.163	165.408	0.0005

CI = confidence interval

3. Evaluation of cause of failure in previous microsurgery

Distribution of the failure cases, defined (a) to (k), is shown in Table 8. The causes of failure were 3 cases (g, i, j) with vertical root fracture, 2 cases (b, h) with cracks, 2 cases (a, d) with periodontal disease, 2 cases (e, f) with unknown, 1 case (k) with prosthetic problem and 1 case (c) with endodontic lesion.

Three cases (i, j, k) that were evaluated as complete healing at one-year follow up by Molven criteria were extracted. Of these 3 cases, 2 cases were extracted because of vertical root fracture; the other case was extracted because of prosthetic problem. 4 cases (h, i, j, k) that were evaluated as PAI score 1, 2, 3 at one-year follow up were extracted. Of these 4 cases, the causes of extraction were 2 cases with vertical root fracture, 1 case with crack, and one case with prosthetic problem.

Of 11 cases, 7 cases (a-g) were evaluated as failure after one-year follow up by both Molven criteria and the PAI scoring system.

Table 8. Distribution of the failed cases

Case	Short-term(one-year) follow up outcome		Cause of failure	Solution
	Molven criteria	PAI score		
a	unsatisfactory	5	perio.	root amputation
b	unsatisfactory	4	crack	root amputation
c	unsatisfactory	4	endo.	apical re-surgery
d	unsatisfactory	4	perio.	extraction
e	unsatisfactory	5	unknown	extraction
f	unsatisfactory	4	unknown	extraction
g	unsatisfactory	4	VRF	extraction
h	uncertain	3	crack	extraction
i	complete	2	VRF	extraction
j	complete	1	VRF	extraction
k	complete	1	prosthe.	extraction

PAI=periapical index, VRF=vertical root fracture, endo=endodontic lesion, perio= periodontal problem, prosthe= prosthetic problem

IV. Discussion

Many outcome studies for endodontic microsurgery were done in a period of approximately one-year.(Chong et al., 2003; Christiansen et al., 2009; Filippi et al., 2006; E. Kim et al., 2008; Richard et al., 1999; Taschieri et al., 2006; Taschieri et al., 2008; von Arx et al., 2003) Complete/ unsatisfactory healing group are defined, and cases belonging to these groups may be expected to remain unchanged (Rud et al., 1972a). However, the two groups, incomplete healing and uncertain healing, showed changes into different groups with time (Rud et al., 1972a). With observation periods exceeding four years, the groups showed only minor changes (Rud et al., 1972a). Consequently, a four-year observation period was proposed as the final follow up in cases showing uncertain healing. Although healing peaks in the first year after the apical surgery, a reversal to disease occurred in 5-25% of the apparently healed cases within four years after treatment (Halse et al., 1991). Accordingly, Friedman (Friedman, 2011) argued that the short term outcomes are expected to outperform the long-term results.

On the other hand, Zuolo et al. (Zuolo et al., 2000) clearly demonstrated that for modern filling materials used in microsurgery, a healing peak with subsequent decline in successful outcome does not exist. Cases that were considered healed within 1 year stayed healed and even after 4 years did not change.

Rubinstein and Kim (Rubinstein and Kim, 2002) carried out a 5-7 year follow up on 59 sample of apical microsurgeries which were initially regarded as healed.

Among the 59 roots, 54 (91.5%) remained healed, whereas 5 (8.5%) showed signs of apical deterioration. Among these, only one was identified as failure. Moreover, this failure was due to a restorative failure, not attributed to endodontic surgery.

Most of the successful cases at one-year follow up maintained stable conditions over the years. Under the Molven criteria, of 92 cases classified as complete/incomplete healing at one-year, 89 cases (96.7%) remained so at long-term follow up. Regarding to the PAI scoring system, of 94 cases classified as successful (score 1-3) at one-year, 90 cases (95.7%) remained so at long-term follow up. Radiographic examination revealed either no change in bone density or continued deposition of periradicular bone (**Fig 1**). Clinical examination was also uneventful and confirmed sustained healing.

According to Rud et al.(Rud et al., 1972a) and Halse et al. (Halse et al., 1991), two groups, incomplete healing and uncertain healing, underwent a number of changes compared to other healing groups during the follow up period. In this study, 19 cases considered healed by scar tissue (incomplete healing) at the one-year follow up, of which 13 cases exhibited further reduction of the radiolucency and 6 cases maintained stable conditions. This is consistent with the findings of Molven et al. (Molven et al., 1996) and Rubinstein and Kim (Rubinstein and Kim, 2002).

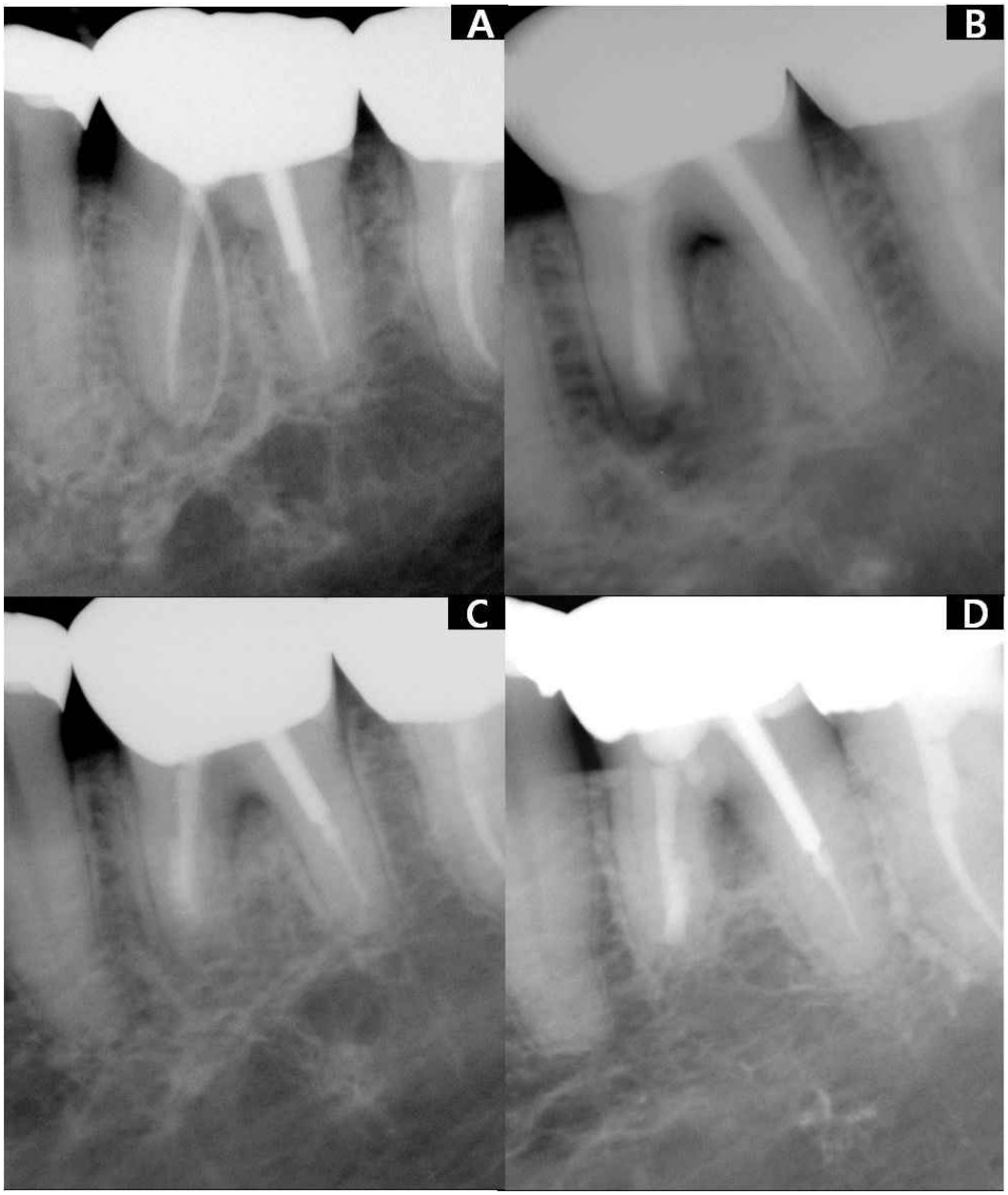

Figure 1. An example of stable case: Typical case illustrating stable outcome of endodontic microsurgery.

(A) Preoperative radiograph with periapical raiolucency and gutta-percha tracing. (B) Postoperative radiograph. (C) Radiograph at one-year follow up. (D) Radiograph at six years follow up.

Molven et al.(Molven et al., 1996) followed 24 cases treated by periapical surgery which 2–6 years after surgery were classified radiographically as incomplete healings (scar tissue). They were followed further, extending the observation period to 8–12 years. Of these, 1 case healed completely, 1 case failed, and 22 cases were still in the same healing group. This led the researchers to conclude that cases that exhibit scar tissue at one–year after surgery can be considered successful. Rubinstein and Kim (Rubinstein and Kim, 2002) followed 6 cases considered healed with scar at one–year for an additional 5 – 7 years. 5 cases exhibited further reduction of the radiolucency and 1 case failed.

In this study, 4 cases were classified radiographically as uncertain healing at one–year follow up, of which 3 cases changed into incomplete healing and 1 case failed (**Fig. 2**). This result is not consistent with those of Halse et al. (Halse et al., 1991)'s study. They followed 72 cases treated by periapical surgery, which one–year after surgery were classified radiographically as uncertain healing (partially healed group), for a mean observation period of 4.3 years. Only two cases developed the features of healing by scar tissue (incomplete healing). The rest was equally distributed into the groups unsatisfactory healing or uncertain as earlier.

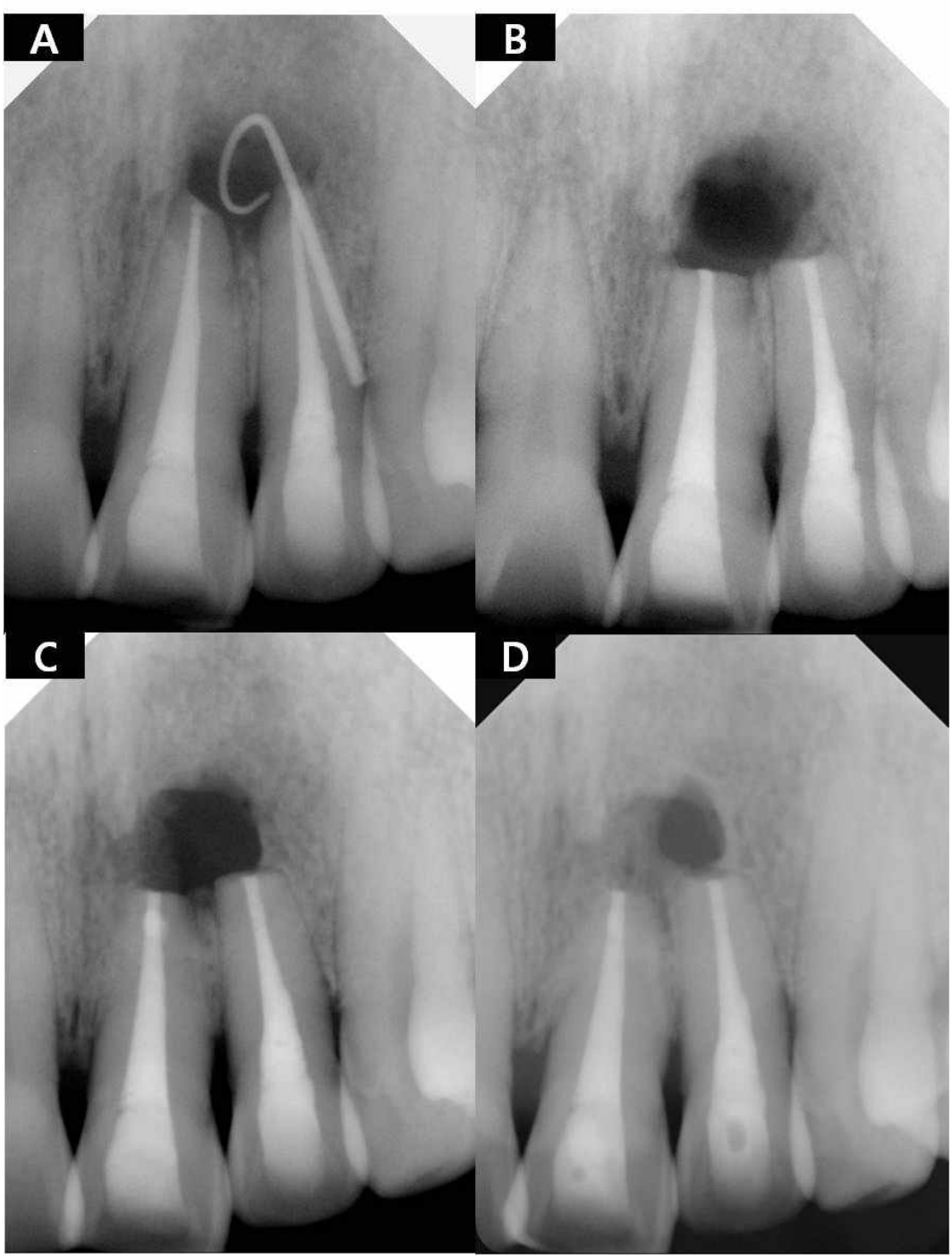

Figure 2. An example of healed case: Categorized to failure group in one-year but healed after long-term follow up

(A) Preoperative radiograph with periapical raiolucency. (B) Postoperative

radiograph. (C) Radiograph at one-year follow up. Tooth #21 was evaluated as uncertain healing in Molven criteria and score 4 in PAI scoring system. Tooth #22 was evaluated as uncertain healing in Molven criteria and score 4 in PAI scoring system. (D) Radiograph at five years. Tooth #21 was evaluated as incomplete healing in Molven criteria and score 1 in PAI scoring system. Tooth #22 was evaluated as incomplete healing in Molven criteria and score 3 in PAI scoring system.

For the cases in which failure occurred, questions concerning the etiology can be raised. For these 11 cases, we either performed extraction, root amputation or endodontic micro-resurgery. Among these, only 1 case had an endodontic lesion, but the tooth was saved by endodontic micro-resurgery. Multirooted molars were maintained by root resection. Among the 11 failed cases, 3 cases were evaluated as complete healing under the Molven criteria and as score 1 or 2 under the PAI scoring system at one-year follow up. The cause of these failed cases was vertical root fracture developed suddenly during the follow up period (Fig. 3). Possibly a pre-existed micro-crack in the coronal area, which was not detected, or the weakening of the tooth due to excessive removal in the course of apical preparation or isthmus preparation could have caused the fracture.

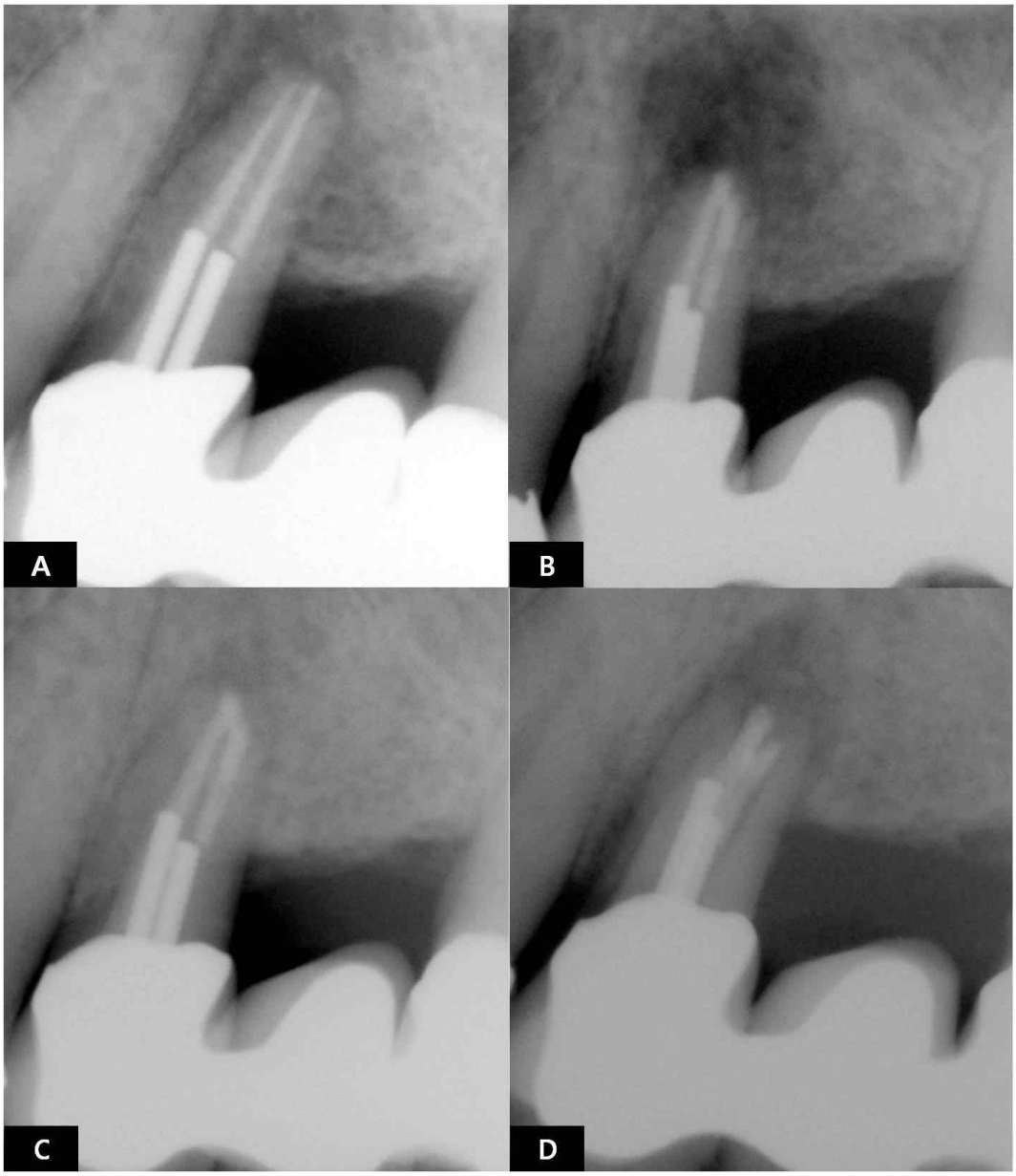

Figure 3. An example of deteriorative case: Categorized to success group in one-year but worsened after long-term follow up (A) Preoperative radiograph with periapical raiolucency. (B) Postoperative radiograph. (C) Radiograph at one-year follow up. This was evaluated as complete healing in Molven criteria and score 1 in PAI scoring system. (D) Radiograph at three years with periapical raiolucency. The cause of failure was vertical root fracture.

We evaluated the follow up outcomes using Molven criteria and PAI scoring system. During long-term period, PAI scoring system was more sensitive than Molven criteria in observation to the healing pattern changes. Under the Molven criteria, there were 82 stable cases, 16 healing cases, and 5 deteriorative cases. Meanwhile, under the PAI scoring system, there were 65 stable cases, 27 healing cases, and 11 deteriorative cases. There were 21 changing cases (healing+deteriorative) under the Molven criteria and 38 cases under the PAI scoring system. This result seems to be due to the different evaluation standards between the Molven criteria and the PAI scoring system: While PAI scoring system only evaluates single radiograph, Molven criteria compare the current and the prior radiographs. Moreover, in the PAI system, boundaries between scoring groups are vague (especially among score 1, 2 and 3), so there are possibilities for interpreters to score subjectively. Molven criteria is divided into 4 healing groups while the PAI scoring system is further divided into 5 scoring groups. Interexaminer agreement was lower in PAI than Molven criteria. However, Molven criteria and the PAI scoring system did not show significant difference in the success and failure results.

The results of logistic regression modelling of the changing pattern between one-year and long-term follow ups were different in Molven criteria and PAI scoring system. The possibility to change into healing categories other than to remain stable, comparing the success group and failure group, were not statistically significant in both Molven criteria and PAI scoring system. However the possibility to change into deteriorative categories other than to remain stable

was not statistically significant in Molven criteria, but was significant in PAI scoring system. There were 5 cases which changed from score 4 to 5 after long-term follow up in PAI scoring system which were scored as same unsatisfactory healing group in Molven criteria. This may explain the differences in the results.

The major problem of long-term follow up study is loss of follow up. Bias occurs in the case of differential loss occurring between the success group and the failure group. Also, great effort and time is needed to retain patient visits. Thus, termination of follow up after one-year would offer practical and economic benefits. In this study, there were many cases lost during the follow up process which could be success or failures. Some patients may have not showed up because they did not have any pain from successful surgeries. Also some patients may have not come to the follow up because they had discomfort after surgeries and had been treated at other dental clinics. However, in this study a significant number of long-term follow up cases were collected and we could observe a clear pattern of changes even after one-year follow up which is of clinical value.

V. Conclusion

In spite of limitations of this study, we were able to conclude that long-term outcomes of endodontic microsurgery can be predicted by one-year outcomes.

During the long-term period, PAI scoring system was more sensitive than Molven criteria in observation of healing pattern changes. However, clinically, the PAI scoring system and the Molven criteria did not show significant differences in assessing the success and failure of the endodontic microsurgery.

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국문 요약

치근단 미세현미경 수술 증례의 장기적인 관찰

: 1년과 4년 이상 경과 후 결과 사이의 변화 양상

대부분의 치근단 미세현미경 수술의 결과에 관한 연구들은 수술 후 1년 안팎의 시간이 경과 한 후 결과를 도출한다. 1년 후의 결과가 장기간 변화하지 않고 유지되는가 하는 것은 논란이 있다. 따라서 본 연구에서는 Molven criteria와 PAI scoring system을 이용하여 치근단 미세현미경 수술 후 1년 후의 결과와 4년 이상(4~8년)의 장기간의 시간이 경과 하였을 때의 결과를 비교하고 변화양상을 관찰하였고, 1년의 결과 후에 실패한 케이스들의 원인에 대하여 고찰하였다.

연세대학교 치과대학병원 보존과에서 2004년 2월부터 2007년 12월까지 치근단 미세현미경 수술을 시행한 환자들의 기록을 검색하였고, 그중에서 수술을 시행한 후 1년 및 4년이상의 시간이 경과한 후 임상 및 방사선학적 평가가 이루어진 환자들을 이번연구에 포함시켰다. 모든 방사선학적 평가는 Molven criteria와 PAI scoring system 으로 평가하였다.

치근단 미세현미경 수술이 시행된 전체 550 케이스 중에서 103 케이스가 이번 연구의 조건을 충족시켰다. Molven criteria로 평가한 경우에서는, 수술 시행 후 1년년 경과하였을 때 92케이스가 성공으로 평가되었는데 이중에서 장기간의 시간이 경과한 후에는 89케이스(96.7%)가 그상태로 유지되었고 3케이스(3.3%)가 실패 그룹으로 악화되었다. 반면에, 1년 후에 11케이스가 실패로 간주되었지만, 이중에서 3케이스(27.3%)가 장기간의 시간이 경과 후에 성공 그룹으로 분류되었다. 통계 분석 결과, 장기간의 시간이 경과후에도 실패 그룹이 성공 그룹에 비하여 더 치유되

거나 악화될 가능성은 없다는 결과가 나왔다. 즉, 장기간의 시간이 경과 후 실패그룹이나 성공 그룹 모두 치유되거나 악화되지 않고 유지된다고 할 수 있겠다.

PAI scoring system으로 평가한 경우에서는, 수술 시행 후 1년년 경과하였을 때 94케이스가 성공으로 평가되었는데 이중에서 장기간의 시간이 경과한 후에는 90케이스(95.7%)가 그상태로 유지되었고 4케이스(4.3%)가 실패 그룹으로 악화되었다. 반면에, 1년 후에 9케이스가 실패로 간주되었지만, 이중에서 2케이스(22.2%)가 장기간의 시간이 경과 후에 성공 그룹으로 분류되었다. 통계 분석 결과, 장기간의 시간이 경과후에도 실패 그룹이 성공 그룹에 비하여 더 치유될 가능성은 없다는 결과가 나왔다. 반면에, 실패 그룹이 성공 그룹에 비하여 더 악화될 가능성은 있다는 결과가 나왔다.

몇가지 제한점들이 존재하지만, 이번 연구를 통하여 치근단 미세 현미경 수술의 장기적인 결과는 수술 후 1년의 결과로 예상 가능하다. PAI scoring system은 Molven criteria보다 변화 양상을 관찰하는데 민감하였지만 임상적으로 치근단 미세현미경 수술의 성공, 실패를 관찰하는데 큰 차이를 보이지는 않는다.

핵심 되는 말: 치근단 수술; 치근단 미세현미경수술; Molven criteria; PAI scoring system; 장기적인 관찰; 결과